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Pleurotus ostreatus: an oyster mushroom with nutritional and medicinal properties

Krishnamoorthy Deepalakshmi, Sankaran Mirunalini *

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Abstract

Mushrooms constitute an integral part of the normal human diet and in recent times, the amounts of consumption have been raised greatly, which includes variety of species. The genus *Pleurotus* comprise about 40 different species that are commonly referred to as "Oyster mushroom". Among several species of this genus, *Pleurotus ostreatus* (*P. ostreatus*) is popularly consumed by all over the world due to their taste, flavor, high nutritional values and medicinal properties. Because of the presence of numerous nutritional compositions and various active ingredients in *P. ostreatus*, have been reported to have antidiabetic, antibacterial, anticholestrolic, antiarthritic, antioxidant, anticancer, eye health and antiviral activities. In this review, we particularly expose the high nutritional values of *P. ostreatus*, in relation to their potential medicinal usage which suggest that the *P. ostreatus* mushrooms are the most important nutraceutical functional foods.

Keywords: *Pleurotus ostreatus*, functional food, medicinal properties, β-D Glucan (pleuran), lectin.

Introduction

Mushrooms are considered as a functional food, which can provide health benefits beyond the traditional nutrients they contain (Cheung et al. 2008). Nevertheless, until the last decade as compared with vegetables and medicial mushroom species, knowledge of the composition and nutritional value of culinary mushrooms was limited. Because, culinary mushrooms have been perceived only as a delicacy and their consumption in many developed countries has been marginal and thus of little interest to researches. However, the situation has started to change noticeable; the yearly number of original papers is now several times higher than 10-15 years ago (Kalac et al., 2012). Among the abundant number of edible mushrooms *Pleurotus* genus is a prolific produced of novel "mycochemicals".

Krishnamoorthy Deepalakshmi, Sankaran Mirunalini*

Department of Biochemistry and Biotechnology, Faculty of Science, Annamalai University, Tamil Nadu, India.

*E-mail: mirunasankar@gmail.com

The origin of *Pleurotus* was first cultivated during the First World War in Germany as a subsistence measure for food storages and the first documentation of cultivation was done by Kaufer (Kaufert F et al.1936). Nowadays, several species of *Pleurotus* are cultivated commercially because of their rich mineral contents and medicinal properties, short life cycle, reproducibility in the recycling of certain agricultural and industrial wastes and low demand on resources and technology (Sibel Yildiz et al. 2002).

And also the substrate used for the harvesting of the *Pleurotus* mushroom is valuable as a fertilizer and a soil conditioner for the growth of plants (Brenneman JA et al. 1994). Additionally, fermented residues could be used as animal feed after mushroom cultivation (Soto-Cruz O et al. 1994). Thus the cultivation process of *Pleurotus* can solve one of the most important problems in soil waste disposal, economical gain and protect the environment.

Many investigations from different region of the world confirmed that the *Pleurotus* mushroom having highly nutrition and also contains various bioactive compounds including terpenoids, steroids, phenols, alkaloids, lectins and nucleotides, which have been isolated and identified from the fruit body, mycelium and culture broth of mushrooms are shown to have promising biological effects (Lindequist et al. 2005). But the findings are mostly scattered. In this review, we have summarized the recent finding regarding many aspects of *Pleurotus* mushrooms.

Pleurotus ostreatus

The binomial name is *Pleurotus ostreatus* (Jacq.ex.fr) P.kumm. The genus *Pleurotus* comprises about 40 species and they are commonly referred to as "oyster mushroom", grow widely in tropical and subtropical areas and easily artificially cultivated. *Pleurotus* genus includes *P. ostreatus*, *P. sajor-caju, P. florida, P. flabellatus, P. highbing 51, P. cystidiosus, P. sapidus, P. eryngii, P. tuberegium, P. ulmarium, P. pulmonarius, P. citrinopileatus, P. geesteranus* and other some of which are of a special consideration due to their high nutritional values and medicinal importance (Kues and Liu

2000; Chang and Miles 1989). Whereas scientific classification of *P. ostreatus* mushrooms were belongs to,

Taxonomic Description

Kingdom	:	Fungi
Phylum	:	Basidiomycota
Class	:	Agaricomycetes
Order	:	Agaricales
Family	:	Pleurotaceae
Genus	:	*Pleurotus*
Species	:	*P. ostreatus*

Mycological Characteristics

Both the scientific and common name refers to the shape of the fruiting body. The Latin *Pleurotus* (sideways) refers to the sideways growth of the stem with respect to the cap, while the Latin ostreatus and the English common name, oyster refers to the shape of the cap which resembles the bivalve of the same name. *P. ostreatus* has a broad, fan or oyster- shared cap spanning 5 to 25 cm natural specimens range from white to grey or tan to dark-brown; the margin is inrolled when young and smooth often somewhat lobed and wavy Fig. 1 shows the fruit bodies of *P. ostreatus*

Flesh: is white, firm and varies in thickness due to stipe arrangement.
Gills: The gills of the mushroom are white to cream and descend on the stalk if present**.**
Stipe: The stipe is off-center with a lateral attachment to wood.
Spore print: The spore print of the mushroom is white to lilac-grey and best viewed on dark surface (Hassen et al. 2011).

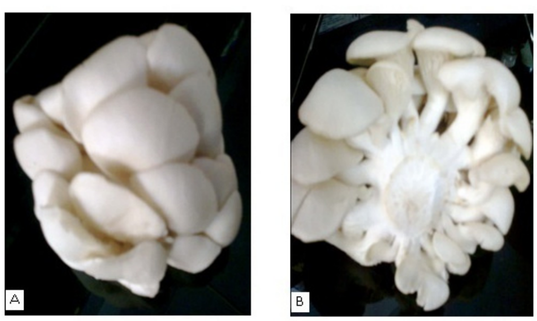

Figure 1: A, B Shows fruit bodies of *Pleurotus ostreatus*

Calorific Value

Owing to the considerable content of water and low calorific value, at 105-209 J in 100 g^{-1} fresh matter of edible mushroom should be regarded as dietary food. Cultivated species of *P. ostreatus* is characterized by a medium calorific value of 151 J in 100 g of edible part respectively (Manzi et al. 2001).

Flavour

Compounds of fungal aroma do not play any essential role in nutrition but they stimulate the appetite and give mushroom dishes a characteristic flavor. Around 150 aromatic compounds are identified in different mushroom species. The main substances responsible for the aroma of most edible mushrooms are octavalent carbonate alcohols and carbonyl compounds, among them 1-octanol, 3-octanol, 3-octanon, 1-caprynol-3-ol, 1-octynol-3-ol, 2-octynol-3-ol and 1-caprynol-3-on (Mau and Hwang 1997). Owing to the presence of compound 1-octynol-3-ol dominates in the fructifications of *P. ostreatus* (Beltran- Garacia et al. 1997). The aroma of the mushroom also depend on the content of amino acids, nucleotides, some other elements such as nitrogen, phosphorus, potassium, sulphur, iron and zinc and also the autoxidation of unsaturated fatty acids (Bernas et al. 2006).

Nutritional Values

Among the world's populations consumes cereal- based food or lives in regions where the soil has a mineral imbalance, which can frequently results in a lack of essential nutrients in their diet (John and Eyzaguirre 2007). However, it can interrupted the routine schedules of many functions such as metabolism, sleep and body temperature are disturbed which leads to several disorders (Mcclung 2007). Thus bioaccumulation potential of nutrients by fungi enriched with essential elements for human health has been investigated in mycelium and also in mushroom (Silva et al. 2010). *P. ostreatus* is the second most important cultivated mushroom for food purposes throughout worldwide (Chang 1991). Nutritionally, it has unique flavor and aromatic properties and it is considered to be rich in protein, fiber, carbohydrates, minerals and vitamins as well as low fat (Herndndez et al. 2003 and Kalmis et al. 2008). Commercially cultivated mushroom has similar contents of nutritional components compared with wild types mushroom. However, there are qualitative and quantitative differences in the chemical composition of *P. ostreatus* products depend upon the strain, origin, extraction process and cultivation conditions (Wang et al. 2001).

Active Constituents

Over large number of reports have been published concerning chemical constituents of *P. ostreatus* and related species. In most of the studies, the nutritional values of mushroom have been offered as in dried fruit bodies. Generally, fresh *Pleurotus* mushroom contain 85-95% moisture (Khan 2010). The fruiting body of *P. ostreatus* contains approximately 100 of different bioactive compounds, which mainly considered as a potential new source of dietary fiber. Whereas, fungal cell wall are rich in non-starch polysaccharides, of which β-glucan are most interesting functional components and phenolic compounds such as protocatechuic acid, gallic acid, homogentisic acid, rutin, myrictin, chrysin, naringin, tocopherol like α-tocopherol and γ- tocopherol, ascorbic acid and β-carotene of each having their own outstanding medical effects (Wang et al. 2001 and Ferreira et al. 2009). Moreover, they are healthy foods, rich in protein, lipids, carbohydrates, vitamin and minerals content but low in calories and fat content (Table 1).

Table 1: Macronutrients of *P. ostreatus* (Khan 2010)

Nutrients	**Content (g/100g dried mushroom)**
Proteins	17-42
Carbohydrates	37-48
Lipids	0.5-5
Fibers	24-31
Minerals	4-10
Moisture	85-87%

Proteins

Mushrooms are rapidly becoming recognized as a promising source of novel proteins. Several proteins showing unique features have been isolated including lectins, lignocellulolytic enzymes, proteases inhibitor and hydrophobins. They can offer solutions to several medicinal and biotechnological problems such as microbial drug resistance, low crop yield and demands for renewable energy. Whereas, large-scale production and industrial application of some fungal proteins proves their biotechnological potential and establishes higher fungi as a valuable although relatively unexplored, source of unique proteins (Jana Erjavec et al. 2012). Although mushrooms are rich source of diverse proteins, not many of these proteins have been identified and even fewer characterized. Whereas, the content of protein in *P. ostreatus* is reported to vary according to strains, physical and chemical differences in growing medium (Akyuz and Kirbag 2010), composition of the substrate, size of the pileus, and harvest time (Mshandete and Cuff 2007). The protein content ranges from 17 to 42 g per 100 g dried fruit bodies, which have been reported from different studies of *P. ostreatus* mushroom (Akyuz and Kirbag 2010, Alam et al. 2008 and Khan et al. 2008). A Lectin is a dimeric protein with a molecular weight of 40 kDa and 41 kDa respectively with antihepatoma and antisarcoma properties was isolated from the fresh fruiting bodies of *P. ostreatus* (Wang H et al. 2000). In addition 7mg of amino acids present in 100 g of edible part of fruit bodies (Mattiala et al. 2001). However, Proteins of *Pleurotus* sp. mushroom have superior quality because some of the members of this genus contain complete proteins with the well distribution of essential amino acids, as well as non-essential amino acids particularly GABA, that act as neurotransmitter and ornithine which is a precursor in the synthesis of arginine (Table 2).

Table 2: Amino acids composition of *P. ostreatus* (Wang et al. 2001)

Amino Acids	**Content (g/100g dried mushroom)**
Aspartic acid	31.4
Threonine*	17.1
Serine	18.1
Glutamic acid	53.3
Glycine	17.1
Alanine	28.6
Valine*	21.0
Cysteine	3.8
Methionine*	3.8
Isoleucine*	16.2
Leucine	25.7
Tyrosine	13.3
Phenylalanine*	15.2
Lysine*	22.9
Histadine	12.4
Arginine	27.6
Tryptophan*	4.8
Proline	15.2
Total essential Amino acids	126.7
Total amino acids	347.5

*The essential amino acids

Lipids

Pleurotus mushroom are low in fat content, but they contain some essential fatty acids. However, mushrooms are not considered as a significant source of essential fatty acids for fulfilling the requirements of human body. Oleic acid is the major monounsaturated fatty acid and linoleic acid is the major polyunsaturated fatty acid in *P. ostreatus*. According to the report of Hossain et al. 2007 *P. ostreatus* contains the monounsaturated fatty acids oleic acid (363μg/g dried mushroom) and the n-6 essential fatty acids linoleic acid (533 μg/g dried mushroom) at the higher concentrations (Hossain et al. 2007). The n-3 essential fatty acid linoleic acid (11.6 μg/g dried mushroom) and arachidonic acid (10.8 μg/g dried mushroom) were also found to be present in *P. ostreatus*. Consequently, the lipid content ranged from 0.2 to 8g per 100g dried fruit bodies, which have been reported from different studies with different species of *Pleurotus* species (Hossain et al. 2007). The nutritional contribution of mushroom lipids is limited due to low total lipid content and a low proportion of desirable n-3 fatty acids. Nevertheless, linoleic acid is a precursor of the attractive smell of dried mushrooms (Kalac. P 2012).

Carbohydrates and fibers

Carbohydrates constitute the prevailing component of mushroom dry matter, usually about 50-60%. The carbohydrate comprises various compounds-monosaccharide, their derivatives and oligosaccharides (commonly called sugars) and both reserve and construction polysaccharides (Glucans), which are important in the proper functioning of the alimentary tract (Kalac 2012). Conversely, *P. ostreatus* mushroom are considered as a good source of carbohydrates and dietary fibers. Carbohydrates which are mainly present in *P. ostreatus* as polysaccharides are represented by glycogen and such indigestible forms as dietary fibers, cellulose, chitin, α- and β- glucans and other hemicelluloses like mannans, Xylans and galactans (Hossain et al. 2007 and Manzi et al. 2001).The glucans are present with different types of glycosidic linkages, such as branched (1→3), (1→6)-*β*-glucans and linear (1→3)-*α*- glucans. *P. ostreatus* contains a specific β-glucan called pleuran, which serves as a source of antitumor polysaccharides. The composition of these polysaccharides in the fruit bodies vary with the strains, ranging from 37 to 48 g/100 g dry fruit bodies (Synytsya et al. 2008).

Mushrooms are a potential source of dietary fibers due to the presence of non-starch polysaccharides. Whereas, the stem part of the mushroom contained more insoluble dietary fibers than the pilei in all the cases. However, the total dietary fiber (TDF) in mushrooms is the sum of intrinsic non-digestible carbohydrates mainly chitin (Vetter 2007). Mushroom glucans are also components of soluble (SDF) or insoluble (IDF) dietary fiber (Prosky et al. 1988). Their solubility in water strongly depends on the molecular structure and conformation. Nevertheless, the information of dietary fiber content of mushroom has been limited. Kalac et al., have reported that about 4-9% and 22-30% for soluble and insoluble fiber, respectively (Kalac et al. 2009). It is evident that mushroom contains other structural polysaccharide in addition to chitin. According to Manzi et al., reported that the content of dietary fiber in 100g of edible parts ranges from 4.1 g in *P. ostreatus* mushroom (Manzi et al. 2001).

Vitamins

Trace elements are essential for human health, which having important physiological effect on different organs and cellular mechanisms. Mushrooms fruit bodies are rich in vitamins, mainly vitamin-B_1, vitamin- B_2, vitamin-C and vitamin-D_2 (Manzi et al. 2004). The vitamin of group B are abundant particularly thamine, riboflavin, pyridoxine, pantotene acid, nicotinic acid, nicotinamid, folic acid and cobalamin as well as other vitamins such as ergosterol, biotin, phytochinon and tocopherols (Mattiala et al. 2001). With respect to thiamine content, mushrooms are a bridge between yeast and other food products of vegetal origin. *P. ostreatus* contains more folacine, vitamin B_1, vitamin B_3 but less vitamin B_{12} than other mushroom species. The vitamin content (mainly vitamin B complex) of *P. ostreatus* mushroom is shown in (Table 3).

Mineral constituents

Like all living organisms, *Pleurotus* mushrooms have a mix of minerals and their fruiting bodies are characterized by high level of mineral constituents.

Table 3: Vitamins content of *P. ostreatus* mushroom (Wang and Ng 2000 and Mattila et al. 2006)

Vitamins	Contents (mg/100g dried mushroom)
Thiamin	1.9-2.0
Riboflavin	1.8-5.1
Niacin	30-65
Folate	0.3-0.7
Ascorbic acid	28-35

The vitamins and minerals content also vary with composition of substrates and time of harvest.

The fructifications of mushroom are characterized by a high level of well assailable mineral constituents (Mattiala et al. 2001). But the whole mineral level depends, among other things like the species and age of the mushrooms, the diameter of the pilei and on the substratum (Demirbas 2001). According to Vetter et al., reports the distribution of these substances in the fructification varies and their content is usually greater in the pileus than in the stipes. The pilei of *P. ostreatus* have greater content of copper, iron, potassium, magnesium, phosphorous and zinc and the stipes of the pilei of *P. ostreatus* have greater content of sodium (Vetter et al. 1994 and Watanable et al. 1994). The mineral content of *P. ostreatus* were reported in (Table 4). However, the bioavailability of these mineral content in *Pleurotus* mushroom needs to be tested in animal and human studied. According to Manzi et al. 2001 in 100 g of edible part of *P. ostreatus* the content of ash is 0.8 to 0.9 g respectively.

Table 4: Minerals content of *P. ostreatus* mushroom (Khan et al. 2008 and Chihara et al. 1992)

Minerals	Contents (mg/100 g dried mushrooms)
Potassium	1400
Calcium	2-36
Sodium	3
Magnesium	9-17
Zinc	3-27
Iron	55-65
Manganese	0.5-3
Copper	0.65
Selenium	0.011

Enzymes

A characteristic trait of the composition of mushrooms is the occurrence of various enzymes, which are never or only rarely found in other organisms. The content of oxidative oxidases, fat splitting lipases, inverting enzymes and proteolytic enzymes in mushrooms, most investigations concentrate on the activity of polyphenoloxidases (Espin and Wichers 1999). According to Ratcliffe et al., 1994 various species of mushroom manifest different enzymatic activity is characterized by a higher activity of polyphenoloxidase compound in *P. ostreatus*. The effect of this enzyme is due to the catalysis of phenol compound oxidation, causing a rapid darkening of harvested mushrooms, which in turn reduces their sensory and nutritive properties. Conversely, the darkness of product decreases their keeping quality and hence their market value (Devece et al. 1999).

Medicinal Properties

Traditionally medicinal properties of mushrooms have been well demonstrated particularly in eastern Asian countries. Currently, in some parts of the world, there is a renaissance of interest in traditional remedies. Although there are limited direct human intervention trials, there is a rapidly growing volume of *in vitro* and *in vivo* animal trials describing a possible range of health benefits.

Table 5: Medicinal effects and active compounds of *P. ostreatus* mushroom

Pharmacological Effect	Substances	References
Anticancer	Water soluble protein (or) polysaccharides	Jedinak A et al (2010) Wu et al (2011) De Silva DD et al (2012)
Antioxidant	β-D Glucan (pleuran) Lectin	Bokek P & Galbavy S (2001) Wang H &Ng TB (2000) Zhang YX et al (2012) Mitra P et al (2013)
Antitumor	β-D Glucan (pleuran) Glycopeptides Proteoglycans	Bokek P & Galbavy S (2001) Li et al (1994) Sarangi I et al (2006) Silva S. et al (2012) Devi KSP et al (2013)
Antiviral	Ubiquitin-like protein	Wang H &Ng TB (2000) Ei-Fakharany et al (2010)
Antibacterial	β-D Glucan (pleuran)	Karacsonyi S & Kuniak L (1994) Mirunalini S et al (2012) Vamanu E et al (2012)
Antidiabetic	Unspecified bioactive	Krishna S & Usha PTA (2009) Ghaly et al (2011) Bindhu ravi et al (2013)
Antihypercholesterolic	Lovastatin	Bobek P et al (1995) Weng TC et al (2010)
Eye health	Unspecified bioactive	Isai M et al (2009)
Anti-arthritic	β-(1,3/1,6)D-glucan	Bauerova et al (2009)

Since, there are large amount of compounds like lectins, polysaccharides, polysaccharide-peptides, polysaccharide-protein complex have been isolated from mushroom and these compounds have been found to have antioxidant, anticancer, antimicrobial, antidiabetic, antihypercholestrolemic and immunomodulatory properties (Cohen et al. 2002 and Bobek and Galbavy 2001) (Table 5). Pharmacological properties of *P. ostreatus* were illustrated in Figure 2.

Antibacterial

Karacsonyi and Kuniak (1994) isolated an alkaline-isolated skeletal β-D Glucan from fruiting bodies of *P. ostreatus*. The β-D Glucan (pleuran) promoted the survival of mice susceptible to bacterial infections (Karacsonyi and Kuniak 1994). However, the observed phenolic and tannin constituents of *P. ostreatus* may also elicit antibacterial activity as found in many medicinal plants with mechanisms of action characterized by cell memberane lysis, inhibition of protein synthesis, proteolytic enzymes and microbial adhensins (Cowan, 1999). The antimicrobial potency of the oil of the macrofungus extracted with petroleum ether and acetone, both extracts were observed to inhibit the gram positive and gram negative bacterial tested *in vitro* to suggest that *P. ostreatus* has a broad-spectrum antibacterial activity (Iwalokun BA et al., 2007). Whereas, organic extracts (methanol and chloroform) of *P. ostreatus* has been manifested as effective against Gram-positive

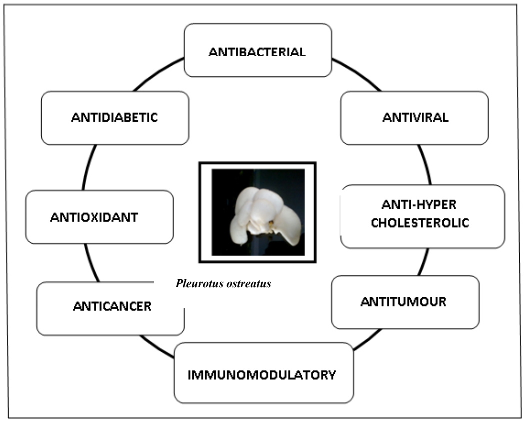

Figure 2: Pharmacological properties of *P. ostreatus*

bacteria which showed to be a potential source of antibacterial agents (Karaman et al. 2010). Moreover, we already studied the antibacterial activity of *P. ostreatus* and biosynthesized silver nanoparticales using *P. ostreatus* against gram positive bacteria was evaluvated using standard zone of inhibition, in which synthesized silver nanopartical using *P. ostreatus* showed maximum zone of inhibition (Mirunalini et al. 2012).

Antiviral

The goal of the antiviral chemotherapy is the discovery of antiviral agents that are specific for the inhibition of viral multiplication without affecting normal cell division. It is necessary to identify and develop new antiviral agents without adverse side effect and viral resistance. EI Fakharany et al 2010 reported that a laccase has been purified from *P. ostreatus* mushroom, which is capable to inhibit the hepatitis C virus entry into peripheral blood cells and hepatoma $HepG_2$ cells and its replication (Ei-Fakharany et al. 2010). Whereas, isolation of a novel ubiquitin-like protein from *P. ostreatus* mushrooms manifest an inhibitory activity toward HIV-1 reverse transcriptase (Wang and Ng 2000).

Antidiabetic

Hyperglycemia is an important feature of diabetes mellitus. The combination of *P. ostreatus*, *Murraya koenigii* and *Aegle marmelos* was oral administration to alloxan induced diabetic rats, and it revealed that the combination produced synergistic effects have been showed blood glucose-lowering effect in both insulin-dependent and insulin-independent diabetic conditions (Krishna and Usha 2009). However, to evaluate the antihyperglycemic action of oyster mushroom (*P. ostreatus*) and its effect on potential DNA damage, chromosome aberration and sperm abnormalities in Streptozotocin induced diabetic rats. Moreover, the results showed that the treatment with *P. ostreatus* extract (especially high level) could reduce the high blood glucose level in hyperglycemic rats but less than amaryl treatment. However, the mushroom treatments were more effective for decreasing the genetic alterations and sperm abnormalities in diabetes conditions than amaryl treatment (Ghaly IS et al., 2011). Bindhu Ravi et al postulated that antidiabetic potential of oyster mushroom *P. ostreatus* in alloxan-induced diabetic mice. This study showed that the *P. ostreatus* produced a significant hypoglycemic effect in diabetic mice and it is capable of improving hyperlipidemia and the impared kidney functions (Bindhu ravi et al., 2013). These findings suggest that *Pleurotus* mushroom are promising as an antidiabetic nutraceutical; but there is lack of enough clinical evidences. The mechanism behind the antidiabetic effect of *Pleurotus* mushroom is not clear.

Antioxidants

Oxidative stress has been implicated as a primary factor in the progression of many degenerative diseases like cancer and hepatotoxicity. Nevertheless, antioxidants such as phenolic and flavonoid compounds are delaying and inhibiting oxidative processes. Generally, *Pleurotus* mushrooms are rich in vitamin and selenium content which are the important natural antioxidants in biological systems (Chang and Miles 1989). Jayakumar et al., 2010 reported that, an extract of *P. ostreatus* enhanced the Catalase gene expression and decreased the incidence of free radical-induced protein oxidation in aged rats, thereby protecting the occurrence of age-associated disorders that involve free radicals. The ethanolic extract of the oyster mushroom *P. ostreatus* are reported to have potent antioxidant activity in both *in vitro* and *in vivo*. The ethanolic extract exhibit *in vitro* antioxidant activity by virtue of its scavenging hydroxyl and superoxide radicals, inhibiting lipid peroxidation, reducing power on ferric ions, chelating ferrous ions and quenching 2,3-diazabicyclo[2,2,2]oct-2-ene (DBO). It also exhibits as a good *in-vivo* antioxidant activity by reducing the intensity of lipid peroxidation and by enhancing the activities of enzymatic and non-enzymatic antioxidants (Jayakumar et al. 2010).

Yunxia Zhang et al 2012 revealed that the two polysaccharide fraction (PSPO-1a and PSPO-4a) were isolated from the fruiting bodies of *P. ostreatus* exhibited the stronger DPPH and superoxide anion radical scavenging activity with increased concentration, but less effective on scavenging hydroxyl radical. Among these two polysaccharides PSPO-1a, possess more effective free-radical scavenger than PSPO-4a (Yunxia Zhang et al. 2012). Whereas, free radical scavenging and NOS activation properties of water soluble crude polysaccharide from *P. ostreatus* showed superior antioxidant property which might be due to presence of carbohydrate component mostly β-glucan seemed to be responsible for the antioxidant activity. Consequently, *P. ostreatus* act as good source for the development of antioxidant food additives (Payel Mitra et al. 2013).

Antihypercholesterolic

The ethanolic extract (or) dried fruiting bodies of *P. ostreatus* showed an effective evidence for the anti-hyperlipidaemic activity to the diet of normal wistar male rat and a stain with hereditary hypercholesterolaemia. In this study, addition of the dry oyster fungus to diet significantly increased, by more than two-fold, triacylglycerol (TAG) level in plasma of both group of rats compared with their respective controls. In contrast, the ethanolic extract did not significantly change TAG levels (Opletal et al. 1997). Alam et al reported the cooperative effect of oyster mushroom on lipid profile, liver and kidney functions in hypercholesterolic rats. In which, feeding of hypercholesterolemic rats with 5% powder of *P. ostreatus* and *P. sajor-caju* reduced the plasma total cholesterol (TC) level (by 37% and 21% respectively) and triglycerides (TG) level (by 45% and 24% respectively) due to presence of active substance Lovastatin (Alam et al. 2009).

Anticancer activity

Different types of extract from *P. ostreatus* have been demonstrated as potential anticancer agents in different cancer cell lines and experimental animals. However, clinical evidence of anticancer activities of *P. ostreatus* mushrooms has not been established clearly.

Gu, YH was screened the anticancer activity of *P. ostreatus* against human androgen-independent prostate cancer PC-3 cells (Gu and Sivam 2006). And, it was found that a water-soluble extract prepared from the fresh *P. ostreatus* produced the most significant cytoxicity and induced apoptosis in PC-3 cells as dose dependent manner. According to Iris lavin et al., 2006 postulated that an aqueous polysaccharide extract from the edible mushroom *P. ostreatus* induces anti-proliferative and pro-apoptotic effects on HT-29 colon cancer cells. Owing to the presence of newly identified low molecular weight α-glucan with promising anti-tumorigenetic properties, and demonstrated its direct effect on colon cancer cell proliferation via induction of programmed cell death (Iris lavi et al. 2006). Moreover the hot water extract of *P. ostreatus* also showed suppression in proliferation of MCF-7 human breast cancer cells (Martin and Brophy 2010). The methanol extract of *P. ostreatus* has been tested on some breast and colon cancer cells by Jedinak and silva et al., 2008. The extract suppressed the proliferation of breast cancer (MCF-7, MDA-MB-231) and colon cancer (HT-29, HCT-116) cells, without affecting proliferation of epithelial mammary MCF-10A and normal colon FHC cells. Flow cytometry analysis revealed that the inhibition of cell proliferation of *P. ostreatus* was associated with cell cycle arrest at G0/G1 phase in MCF-7 and HT-29 cells. Moreover, *P. ostreatus* induced the expression of the tumor suppressor P^{53} in MCF-7 cells and cyclin-dependent kinase inhibitor P^{21} in both MCF-7 and HT-29 Cells. It also inhibited the phosphorylation of retinoblastoma Rb proteins in MCF-7 and HT-29 cells (Jedinak and Silva 2008).

Pleterova RD et al., 2007 postulated that *P. ostreatus* showed an inhibitory effect on I□Bα phosphorylation possessing biological activity related to immunoenhancement and *invitro* anti-cancer agent (Pleterova RD et al. 2007). However, *P. ostreatus* treatment significantly down-regulated expression of biomarkers involved in colon cancer progression like cyclin D_1 and Ki-67. These clearly indicate that administration of *P. ostreatus* prevented 2-amino-1-methyl-6-phenylimidazo [4,5-b] pyridine (PhIP) and dextran sodium sulfate (DSS) induced mouse colitis-related colonic tumorigenesis without any adverse effect (Jedinak A et al. 2010). The protein extract of *P. ostreatus* has been exhibited therapeutic efficacy against human colorectal adenocarcinoma cell line (SW 480 cells) and a human monocytic leukemia cell line (THP-1cells) by induced apoptosis in SW 450 cells partially through Reactive Oxygen Species (ROS) production, Glutathione (GSH) depletion and mitochondrial dysfunction (Wu et al. 2011). Therefore the protein extract of these mushrooms could be considered as important source of new anti-cancer drug. An overview of anti-cancer activities of *P. ostreatus* as specified in Fig. 3 (Chi HJ Kao et al. 2013).

Antitumor

The very first report showed anti-tumor activities of a *P. ostreatus* polysaccharide fraction in 1972 by Yoshioka et al. Another study showed that the *P. ostreatus* fruiting body extract exhibited anti-tumor, hypocholestrol effect and hypotensive activity (Buswell JA and Chang ST et al. 1993). However, the antitumor effect of *P. ostreatus* mycelia derived proteoglycans was screened against sarcoma-180-bearing mouse model, it was found that *in vivo* injection of proteoglycan to sarcoma-180-bearing mice decreased the number of tumor cells and cell cycle analysis showed that most of the cells were found to be arrested in Pre-G(0)/G(1) phase of cell cycle. The proteoglycans elevated mouse natural killer (NK) cell cytotoxicity and stimulated macrophages to produce nitric oxide. The Fourier transform infra red (FTIR) spectra suggested that beta-glycosidic bond in all the fraction of proteoglycans which strongly interacted with glucose/mannose-specific lectin concanvalin A (Con A), indicating the presence of large number of terminal sugar with glucose and mannose. This suggested that proteoglycans derived from the mushroom (*P. ostreatus*) mycelia could be used as anti-cancer agents (Sarangi et al. 2006). Whereas, Sanjana et al., postulated that a novel water soluble glucan (hetroglucan) from the pure mycelia of *P. ostreatus*. This hetroglucan folded into a triple helical conformation and exhibited enhanced immune cell activation and anti-tumor potential in tumor bearing mice model. Thus potential biological functions incorporated in these glucan molecules acts in accord with its structural property and exploration of such structure-function relationship will unveil its diverse mechanism of action (Devi KPS et al. 2013). Thus the anti-tumor properties of this species are related to the production of heteroglucans (Wasser SP and Weis AL et al. 1999).

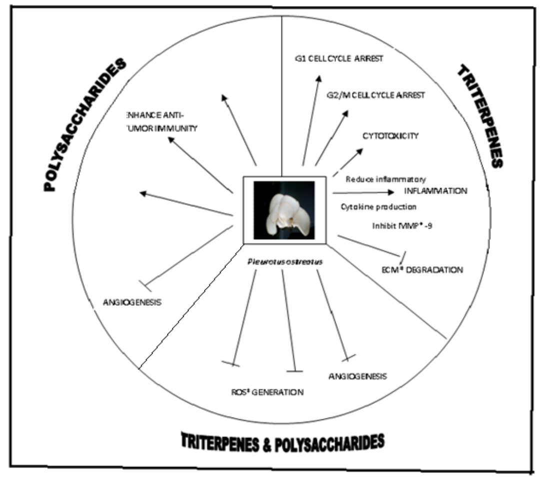

Figure 3: An overview of anti-cancer activities by triterpenes and polysaccharides from *P. ostreatus* (Chi HJ Kao et al., 2013). [ECM* Extracelluar matrix; ROS Reactive oxygen species; MMP* Matrix metalloproteinase]

Immunomodulatory Properties

Immunomodulatory properties alone with low cytotoxicity raise the possibility that it could be effective in the cancer patients receiving conventional chemotherapy and radiational treatment, to build up immune resistance and decreased toxicity. A large number of compounds like lectins, polysaccharides, polysaccharides-peptides, and polysaccharide-protein complex have been isolated from mushroom and many of these compounds have been found to have immunomodulatory effects (Wang et al. 2000). Although mode of actions of these compounds is not clear, nevertheless these are suggested to enhance cellular components of the immune system (Chihara et al. 1992). It has been reported that water extract from fruit bodies and mycelia of *P. ostreatus* has a role in increasing the production of reactive oxygen species (ROS) from neutrophil and has immunomodulatory properties involving all immunocompentent cells (Shamtsyan et al.

2004). However, the bioactivities of the polysaccharides depends on the binding on the lectin-like surface receptor of the immune cells. However Sarangi et al 2006 postulated that Fraction I and ion exchange – passed fraction (crude) strongly interacted with glucose/ mannose- specific lectin Con A, indicating the presence of large number of terminal sugars with glucose/ mannose. These three fractions are not structurally similar but their bioactivities are comparable, which may be due to their differential binding to the immune receptors (Sarangi et al. 2006).

Conclusion

As we seen through the review, *Pleurotus ostreatus* a novel edible mushroom with high nutitional and biomedical importance, since it contains a number of bioactive components develop its large number of therapeutic function. Moreover, due to high nutritional values, these mushrooms may provide significant support against malnutrition disease. Thus the majority of research programs had been focused on extract from the fruiting body and there have been fewer studies on extract from the cultivated fungi. Therefore, further research may be oriented in that direction. Since, most of the therapeutic effects of *P. ostreatus* are based on *in vivo* and *in vitro* studies, clinical trials are needed to fully realize its potentials.

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